THE UNIVERSITY OF ALBERTA

ENERGY DIGESTIBILITY, NITROGEN RETENTION, EFFICIENCY OF FEED UTILIZATION AND CARCASS CHARACTERISTICS OF PIGS FED VARYING LEVELS OF FAT AND PROTEIN

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ABSTRACT

Experiments were designed to study the value of inedible fat as an energy source in swine rations. The criteria of measurement were average daily gain, feed consumption, efficiency of feed utilization, carcass characteristics, energy and nitrogen digestibility and nitrogen retention. Supporting metabolism and feeding studies were conducted with rats. A 3 x 3 factorial design, with rations containing 0, 15 and 30% supplemental fat and 14, 18 and 22 percent protein was used in these studies.

The apparent digestibility of energy was not influenced by fat or protein levels in the rations of 15 or 100 lb. pigs but was improved by increased protein levels in the diets of rats.

Apparent digestibility of nitrogen was not affected by fat levels in the rations of 15 and 100 lb. pigs nor by protein levels in the diets of rats or 15 lb. pigs. Increased fat levels in the diets of rats and increased protein levels in the rations of 100 lb. pigs improved the percentage apparent digestible nitrogen.

Nitrogen retention was not altered by fat levels in the rations. Increased protein levels did not significantly affect nitrogen retention in rats nor in 15 lb. pigs but decreased retention in 100 lb. pigs.

The addition of 15 or 30% supplemental fat to the ration of pigs increased average daily gain, decreased feed consumption and improved efficiency of feed utilization. Protein levels of 18 or 22% in the ration resulted in increased rate of gain, increased feed consumption and improved efficiency of feed utilization as compared to protein levels of 14 percent. The results of the rat feeding experiment were similar except that neither fat nor protein levels of the rations influenced rate of gain.

Carcasses of pigs receiving 15 or 30% supplemental fat in their rations had an increased thickness of backfat and increased dressing percentage as compared to those receiving no supplemental fat. As protein levels of the rations were increased, average backfat thickness decreased and area of loin muscle increased.

Fat as a source of energy was well utilized by growing and finishing pigs from 15 to 195 lb. liveweight but the addition of 15 or 30% fat in substitution for wheat in the ration resulted in the production of inferior quality carcasses. Increased protein levels resulted in beneficial effects on rate of gain, feed consumption, efficiency of feed utilization and carcass quality but did not entirely counteract the deleterious effects on the carcasses of supplemental fat in the rations.

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INTRODUCTION

Animal fat is at present a surplus by-product from the meat packing industry. As a result, the price of fat has been depressed and this has caused the livestock industry to become "fat" conscious. The addition of inedible animal fat as an energy source to livestock rations has provided a possible market for this product. Fat is in theory an excellent source of feed energy supplying approximately 2.25 times as much energy per unit as carbohydrate.

In swine feeding, it has been shown that reasonably low energy rations are necessary in the finishing period to give the most desirable carcasses, but it may be that maintenance of a proper protein-energy ratio with high energy feeds will give acceptable carcasses along with faster and more efficient gains. Higher energy rations are used in feeding pigs in the earlier growing period so that supplemental fat may not be harmful at this stage.

According to present feeding standards, commercial hog rations based on cereal grains contain enough fat to meet the requirements of the pig for essential fatty acids. Therefore, if fat feeding is to be profitable, increase in gain, and particularly improvement in efficiency of feed utilization, must be great enough to offset the higher cost of fat when it is substituted for the normal energy sources in a ration.

The studies reported in this thesis were conducted to determine the value of inedible fat as a replacement for grain in swine rations. The criteria of measurement were average daily gain, feed consumption,

efficiency of feed utilization, carcass characteristics, energy digestibility and nitrogen retention. The experiments were supported by studies with rats.

LITERATURE REVIEW

A survey of the literature reveals that most of the early experimental work on supplementing rations with animal fats was done with poultry. Therefore, a brief review of some of these studies is given.

EFFECT OF ADDING ANIMAL FAT TO POULTRY RATIONS

Sunde (1956) reported that the palatability of a ration was improved by the addition of fat. Feeding a number of different grades of fat, he found that efficiency of feed utilization was improved in all cases by the addition of fat. Improved efficiency of feed utilization has also been reported by Arscott (1958) and Beilharz and McDonald (1959) when fats were added to poultry rations, and by Waibell (1958) when supplemental fat was added to turkey rations.

Waibell (1958) obtained a marked improvement in rate of gain with dietary animal fats, provided that the protein level was adequate. Arscott (1958) showed that the addition of 3 and 6% fat to the ration resulted in improved rate of gain in chickens; however, with 9% fat gain was adversely affected. Curtin et al. (1956) did not obtain any consistent improvement in gain through the addition of fat. Similarly, later work by Beilharz and McDonald (1959) indicated that added fat had no effect on rate of gain.

EFFECT OF ADDING FAT TO SWINE RATIONS

Conflicting experimental evidence also exists concerning the value of adding fat to increase the energy content of growing and finishing swine rations. Abernathy et al. (1958) reported that the addition of 5 or 10% stabilized tallow to the rations resulted in an increased rate of gain and an improved efficiency of feed utilization. Similarly, Kennington et al. (1958) reported an increased rate of gain and improved efficiency

of feed utilization by the addition of fat at levels of 10, 15 and 20 percent. Similar results were previously reported by Barrick et al. (1954). Anderson et al. (1957) found that the inclusion of 2.5, 5, 8 or 10% animal fat in rations fed to growing-fattening pigs improved average daily gain and efficiency of feed utilization. The most efficient use of fat was obtained when the rations contained levels of 5 or 8 percent. Catron et al. (1953) feeding baby pigs, found that a fat level of 10% in the ration resulted in faster rate of gain than did levels of 20 or 30 percent.

Gesler et al. (1957) also obtained an increased rate of gain through the addition of 10% tallow to pig rations. Efficiency of feed utilization was increased until the pigs reached a weight of 120 lb., but no increase was obtained from 120 to 195 lb. body weight. Heitman (1956) feeding stabilized tallow at a level of 5 and 10%, reported an increase in rate of gain but no effect on efficiency of feed utilization. Barnes et al. (1959) obtained a beneficial effect of added beef tallow on rate of gain and efficiency of feed utilization of swine when a high protein (18%) ration was fed, but a reduction in performance when a low protein (10%) ration was used.

Several groups of workers have observed little effect on rate of gain when fat was added to the ration. Perry et al. (1953) found no difference in rate of gain, but feed efficiency was improved by the addition of 1 to 10% lard to rations of growing pigs. Baird et al. (1958) also found that increasing the caloric density of a ration by adding supplemental fat improved efficiency of feed utilization; however, no significant effect on rate of gain was observed. Kropf et al. (1954) were not able to obtain a consistent increase in average daily gain from

the addition of 10 or 15% waste beef fat to swine rations. However, efficiency of feed utilization was improved by the addition of fat to the ration. In more recent work Baird and McCampbell (1960) stated that added fat generally improved average daily gains, but this improvement was not always statistically significant.

Very little work has been reported on the addition of fat to rations of pigs under 8 weeks of age. Asplund et al. (1960) found that stabilized white grease did not improve rate of gain or efficiency of feed utilization when fed to baby pigs.

Perry et al. (1953) reported that average daily feed consumption was lower for pigs receiving higher levels of fat. Later studies by Baird and McCampbell (1960) also indicated that the addition of fat tended to depress average daily feed consumption, which is an expected occurrence when energy levels of a ration are increased. The above reports are in accordance with results obtained by Noland et al. (1960) and Pond et al. (1960). However, it was observed by Pond et al. (1960) that average daily calculated Total Digestible Nutrient consumption was actually increased in the presence of added fat.

The results obtained by Abernathy et al. (1958) did not show any significant increase in carcass backfat thickness from the addition of fat to the ration. This was in substantiation of the report by Kropf et al. (1954) who did not find any clear-cut effect of added fat upon dressing percentage or carcass backfat thickness. In contrast, however, Kennington et al. (1958) reported an increase in backfat thickness from the addition of fat to swine rations.

EFFECT OF PROTEIN AND/OR ENERGY ON RATE OF GAIN, FEED EFFICIENCY AND CARCASS CHARACTERISTICS OF SWINE

It has been demonstrated in several species that an optimum ratio exists between dietary energy and the requirement for nitrogen; for example, Hill and Dansky (1950) with the chick and Sibbald et al. (1957) with the weanling rat. Although the importance of protein in swine nutrition has been recognized for many years, there is little information as to whether an optimum protein to energy ratio exists. Bowland and Berg (1959) stated that "it is necessary to define the criterion of measurement in hogs, as rate of gain, and efficiency of feed utilization may have different protein-energy optima to that required for high carcass quality".

It has been noted by a number of workers that protein level in the ration affected rate of gain in pigs fed a fixed energy level (Ellis and Hankens, 1935; Hironaka and Bowland, 1954; Jensen et al., 1955; Pond et al., 1960). Tribble et al. (1956) fed protein levels of 12 and 16% and found that when performance for the periods from weaning to 100 lbs. and from 100 to 200 lb. were considered, there were significant differences in both rate and efficiency of gains. It appeared that the 12% protein ration was inadequate for the pigs from weaning to 100 pounds. However, from 100 to 200 lb., pigs on the 12% protein ration made significantly faster and more efficient gains than on the 16% protein ration. As a result they found no differences between protein levels for rate and efficiency of gain from weaning to 200 pounds. Similar results have recently been reported by Aunan et al. (1961) who found that protein levels of 14, 16, or 18% did not have a significant effect on daily gains. However, they obtained a highly significant decrease in daily gain when

weanling pigs were fed a 12% protein ration up to a weight of 125 lb., as compared with those fed 14 or 16% protein. Bowland and Berg (1959) found that in the growing period to 110 lb., high protein rations (21%) resulted in improved feed efficiency as compared to medium protein (17%) rations. Their results further indicated that high protein alone or in combination with high energy improved efficiency of feed utilization in the finishing period.

Likuski (1959) observed that rate of gain from weaning to market weight was generally improved by increasing either the energy content from 64 to 81% T.D.N. or protein content of the rations from 14 to 18 percent. Clawson (1961) found that rate of gain was greatly depressed by increased energy content of the ration when the protein level was inadequate. There was little tendency for the pigs to compensate for low protein intake by over-consumption. He also found that efficiency of feed utilization was improved by increases in both energy and protein content of the ration.

In the report by Bowland and Berg (1959) there was an indication that high protein rations resulted in leaner carcasses and that high energy rations resulted in increased dressing percentage and generally inferior carcasses. Ashton et al. (1955) and Robison et al. (1952) also observed that high protein rations resulted in leaner carcasses. However, in contrast to these findings Catron et al. (1952) reported that percent carcass lean, backfat thickness, and length of body were not affected by protein. Bowland and Berg (1959) and Likuski (1959) also found that neither protein nor energy levels in the ration had any effect on carcass length. Noland et al. (1960), however, reported that pigs fed 16 and 20%

protein rations produced longer carcasses as compared to pigs fed 12% protein rations.

As reported in a thesis by Likuski (1959), carcasses from pigs fed high energy rations had a higher dressing percentage and more backfat than pigs fed rations low in energy. Loin area was independent of the level of energy in the ration, but was increased when the protein level was raised. Indications were that carcass quality was not seriously affected by feeding high energy rations which contained corresponding high levels of protein.

ENERGY AND NITROGEN DIGESTIBILITY AND NITROGEN RETENTION

Digestibility and retention studies require an accurate separation of excreta and this often presents caging problems. Rectangular-type metabolism cages have been successfully used for pigs over 50 lb. in weight (Crampton and Whiting, 1943; Watson *et al*., 1943; Hussar, 1958; Likuski, 1959). For smaller pigs the use of adjustable cylindrical cages has been suggested by Bell (1948). The use of swine harnesses (Kolari *et al*., 1955; Hussar, 1958; Likuski, 1959) has simplified the separation of excreta from male baby pigs.

Mitchell and Hamilton (1935) found that in pigs weighing about 100 lb. there was a higher nitrogen retention as the percent of protein in the ration increased from 9 to 20 percent. They also reported that the digestibility of the protein fraction was not affected by the protein level. However, no mention was made as to whether this was apparent or true digestibility of protein. Later work by Lloyd and Crampton (1955), however, indicated that increasing the protein percentage or decreasing the crude fiber percentage tended to increase the apparent digestibility of the protein. This has been further substantiated by Likuski (1959)

who found that when high protein rations (18%) were fed to rats and to 15, 50 and 110 lb. pigs the coefficients of apparent digestible nitrogen were higher than when lower levels of protein (14%) were fed.

In rat studies Sibbald et al. (1957) found that the percentage of gross nitrogen and apparent digestible nitrogen retained were not related to the nitrogen intake per se but were found to be largely influenced by the ratio of the apparent digestible energy and the apparent digestible nitrogen content of the diet. In further studies Bowland et al. (1958) reported that the addition of fat to the diet of rats resulted in significant improvement in nitrogen digestibility and gross nitrogen retention.

Asplund et al. (1960) reported that the inclusion of 10 and 20% stabilized grease in the ration of 8 week old pigs increased the apparent digestibility of ether extract and protein. In earlier studies, Lowrey et al. (1958) also obtained an increase in the apparent digestibility of the protein by the addition of supplemental fat in pig rations.

Lloyd and Crampton (1957) studied factors which influence the utilization of fat by baby pigs. They found that apparent digestibility was related more closely to the chain length of the fatty acids ingested than to any other factor. Lloyd et al. (1957) further showed that age of pigs influenced apparent digestibility as the average apparent digestibility of dry matter, energy, crude protein, and ether extract was higher for 7 than for 3-week old pigs.

EXPERIMENTAL

OBJECTIVES

The main objective of these experiments was to study the addition of high levels of stabilized tallow* as a source of energy for swine fed rations varying in protein level.

Specific experiments were designed to study:

(1) Rate of gain, efficiency of feed utilization and carcass characteristics of Yorkshire and Landrace - Yorkshire pigs fed 9 rations varying in energy or protein from weaning to market weight.

(2) Energy digestibility and nitrogen retention of pigs averaging approximately 15 and 100 lb. liveweight that were fed 9 rations containing 3 levels each of protein and energy.

Preliminary supporting experiments using diets identical with those used in the swine experiments were conducted with Sprague - Dawley albino rats to study food consumption, efficiency of food utilization, energy digestibility and nitrogen retention. An attempt was made to correlate the data obtained from the experiments conducted with the two species.

FORMULATION OF EXPERIMENTAL RATIONS

The formulation of rations is an important phase of nutritional research. In order to study the addition of high levels of inedible fat it was necessary to use varying levels of protein to maintain comparable protein - energy ratios. In the formulation of these rations it was necessary to make adjustments in mineral and vitamin levels to prevent the possible occurrence of nutritional deficiencies which may result from expected lowered feed intake when energy levels of a ration are increased (Sibbald, 1957; Likuski, 1959).

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* Sta-Y-Fat supplied by Gordon Young (B.C.) Ltd.

Hog rations are generally formulated according to the age and weight of the pigs. Normally, pigs are fed a starter, then a grower and finally a finisher ration which vary mainly in the amount of protein and to a lesser extent in the amount of energy present. However, in this experiment a constant ration was fed for the entire experimental period to get more specific data on energy and protein relationships and to allow a clearer interpretation of the results.

The formulation and composition of the rations fed are given in Table 1.

All rations were mixed at the University Livestock Farm, bagged and stored in the swine barn. Diets fed to rats were kept in sealed jars in the rat room of the Animal Science Laboratory.

METHODS AND PROCEDURES IN SWINE EXPERIMENTS

The swine experiments were sub-divided into 3 separate trials:

(1) Experiment 333 and 333B each contained 36 male pigs which were used to study rate of gain, efficiency of feed utilization, and carcass characteristics from weaning to market weight.

(2) Experiment 333A was conducted with 18 pigs used to study energy digestibility and nitrogen retention at approximately 15 and 90 lb. liveweight.

(3) Experiment 333C was conducted with 18 pigs used to study energy digestibility and nitrogen retention at approximately 100 lb. liveweight.

Information regarding rate of gain, efficiency of feed utilization and carcass characteristics of the pigs from weaning to market weight were also obtained in Experiments 333A and 333C.

In all the experiments the pigs were marked at birth for identification purposes and treated routinely with oral iron. They were

TABLE 1

RATIONS FOR FAT AND PROTEIN EXPERIMENTS

Ration No.	1	2	3	4	5	6	7	8	9
Fat Level (Added) ----------- %	0	0	0	15	15	15	30	30	30
Protein Level (Calculated)--- %	14	18	22	14	18	22	14	18	22
Fat by Analysis ------------- %	1.9	2.1	2.2	16.0	17.8	17.9	30.1	30.4	30.8
Protein by Analysis --------- %	12.9	17.2	21.1	13.3	17.6	21.3	14.0	18.5	22.4
Gross Energy---------- Cal./gm.	3.94	4.04	3.98	4.89	4.82	4.63	5.24	5.34	5.64
ADE Cal./gm. ADN in feed***	202	150	118	237	175	137	237	182	158
Ingredients									
Wheat ---------------------	80.0	70.0	60.0	61.4	51.4	41.4	42.4	32.4	22.4
Corn ----------------------	10.0	10.0	10.0	8.5	8.5	8.5	7.0	7.0	7.0
Sugar ---------------------	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Soybean oil meal (50%) -----	2.7	10.2	17.7	6.3	13.8	21.3	10.2	17.7	25.2
Fish meal (72%) ------------	0.9	3.4	5.9	2.1	4.6	7.1	3.4	5.9	8.4
Ground Limestone -----------	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7
Iodized salt ---------------	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7
B complex-vitamin mix* -----	0.2	0.2	0.2	0.25	0.25	0.25	0.30	0.30	0.30
Vitamin B_{12} (9 mg./lb.)-----	0.14	0.14	0.14	0.16	0.16	0.16	0.20	0.20	0.20
Vitamin A and D** ----------									
Aurofac-10 -----------------	0.05	0.05	0.05	0.06	0.06	0.06	0.075	0.075	0.075
Pro-Strep ------------------	0.05	0.05	0.05	0.06	0.06	0.06	0.075	0.075	0.075
Stabilized fat -------------	0.0	0.0	0.0	15.0	15.0	15.0	30.0	30.0	30.0

* Contains the following B vitamins per pound vitamin mix:

Riboflavin ------------ 2 g.
Calcium pantothenate--- 4 g.
Niacin ---------------- 9 g.
Choline chloride ------ 10 g.
Folic acid ------------ 60 mg.
Pyridoxine ------------ 0.5 mg.

** 1,000,000 I.U. vitamin A and 200,00 I.U. vitamin D in lots 1, 2 and 3, increase of 10% in lots 4, 5 and 6, increase 20% in lots 7, 8 and 9.

*** On the basis of coefficients of digestibility for 100 lb. pigs.

castrated at 2 to 3 weeks of age and later treated with a cadmium compound for control of ascarids. General management, conducting of the metabolism trials and methods of analysis were similar to those reported by Hussar, (1958) and are outlined only briefly.

Feeding Experiments

Experiment 333 was initiated February 27, 1959 and terminated August 12, 1959. A total of 36 male pigs were fed the 9 rations shown in Table 1. The lots were balanced as to breed with 2 littermate Landrace - Yorkshire crossbred pigs and 2 littermate Yorkshire pigs in each lot. The average initial weight of the pigs was 14 lb. at an average age of 33 days.

Experiment 333B was initiated September 24, 1959 and terminated March 30, 1960. This Experiment was a replicate of Experiment 333 and had the same distribution of pigs as to sex and breed. The average initial weight on test was 18 lb. at an average age of 41 days.

Experiments 333 and 333B were designed to study rate of gain, efficiency of feed utilization and carcass characteristics. The pigs were housed in the Muttart feeding barn at the University Livestock Farm. All pigs were individually fed for a period of 1 hour 3 times daily and ran together in groups of 4 when not being fed. Water was supplied in automatic watering bowls and was available to the animals when they were not confined in the feeding stalls. The pigs were weighed at weekly intervals and individual feed consumption data was recorded.

The animals were shipped to market at the first weekly weighing after they reached 190 lb. liveweight. Following slaughter, Canadian Government carcass grades and Record of Performance (National Bacon Hog Policy, 1959) measurements and scores were obtained for all pigs.

Metabolism Experiments

Experiment 333A was initiated June 3, 1959 and terminated February 3, 1960. Nine Tamworth - Yorkshire crossbred male pigs and 9 Yorkshire male pigs were used in these metabolism studies. Experiment 333C was initiated June 27, 1960 and terminated December 14, 1960. Nine Lacombe - Yorkshire crossbred male pigs and 9 Yorkshire male pigs were used in these studies. In each experiment, groups of 2 pigs, 1 of each breeding group, were fed one of the nine rations listed in Table 1. All pigs were fed and managed as outlined under Experiments 333 and 333B.

For the 15 lb. metabolism period the pigs were taken to the animal room at the Animal Science Laboratory. The later metabolism trials were carried out at the University Livestock Farm.

The weanling pigs were allowed to become accustomed to the ration for a period of approximately 10 days or until they reached approximately 15 lb. liveweight. A period of 2 days was allowed for acclimatization in order that the pigs could become accustomed to the metabolism cages. Feed consumed during the acclimatization period and the metabolism period was recorded.

To help prevent scouring, the pigs were treated with soluble Terramycin 1 day prior to moving them from the University Livestock Farm to the animal rooms at the Animal Science Laboratory.

Methods of Collection

Feces were collected using a harness described by Hussar (1958).* It was the same as that used by Likuski (1959). The feces were collected

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* Details of metabolism harness as well as the construction of the waterers, feeders and metabolism cages used for 15 lb. pigs may be found in Hussar's M.Sc. Thesis (1958).

in polyethylene bags which were removed daily. The fecal material was emptied from the bags and the feces were dried at 105^{o} C.

The dried feces were stored in closed glass bottles and upon completion of the experiment the composite samples from each pig were weighed and ground through a 2 mm. mesh screen in a Wiley No. 1 Mill.* A representative sample was stored in a glass stoppered bottle and later analyzed for energy and nitrogen.

Urine was collected in plastic pails containing 50 ml. of 50% H_2SO_4. The acidified urine plus cage washings collected during the 5 day period were filtered and weighed. Five ml. aliquots of the filtered urine were later analyzed for nitrogen content. The weight of the 5 ml. aliquot was determined by weighing a 50 ml. aliquot in a volumetric flask.

Metabolism with 90 and 100 lb. pigs were conducted at the University Livestock Farm in cages described by Hussar (1958). The pigs were kept on trial for a 5 day period during which feed intake was recorded and feces and urine samples were collected. No acclimatization period was required.

Urine samples were collected in plastic pails containing 75 ml. of 50% H_2SO_4. At the conclusion of the trial the weight of the urine plus washings was determined. The sample was thoroughly mixed and an aliquot taken for nitrogen analysis as in the 15 lb. pig trial.

Fecal samples were collected 3 times during the 5 day metabolism period. Total feces from each pig were brought to the laboratory dried, ground and analyzed as in the 15 lb. trial.

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* Wiley No. 1 Mill. Manufactured by A. H. Thomas Co., Philadelphia, U.S.A.

METHODS AND PROCEDURES IN RAT EXPERIMENTS

At 21 days of age, 36 weanling rats of the Sprague - Dawley strain were obtained from the stock colony and 9 groups of 4 rats representing the 9 diets fed were allotted to individual cages. Food consumption and rat weights were recorded at the time of weaning and at weekly intervals until the end of the trial. Ad libitum feeding was practised throughout the experiment. This experiment was initiated June 4, 1959 and terminated June 25, 1959.

Another rat experiment was conducted between July 18, 1960 and August 11, 1960. Thirty - six rats were obtained from the stock colony and 9 groups of 4 rats representing the 9 diets used were allotted to individual cages. Following an acclimatization period of 7 days the rats were placed in metabolism cages. Rats were weighed at weaning and at the initiation and conclusion of the experimental period. Food consumption during this period was recorded and feces and urine were collected. Ad libitum feeding was practised throughout both the acclimatization and metabolism periods.

Prior to use, the metabolism cages were sprayed with a saturated solution of boric acid in 95% ethanol to acidify the urine, thus preventing escape of ammonia before the urine came in contact with the H_2SO_4 in the receiving flask.

Collection of Feces

Feces were collected daily, placed in small aluminum dishes, and dried in an oven at 105° C. Prior to analysis the dried feces were ground in a small Wiley Mill* using a 20 mm. mesh screen.

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* Wiley Mill No. 4276 sold by A.H. Thomas Co., Philadelphia, U.S.A.

Collection of Urine

The urine was collected in 25 ml. of 50% concentrated H_2SO_4 during the metabolism period. On termination of the experiment the cages were steamed and rinsed, the washings being added to the urine. Prior to analysis, the combined urine and washings were filtered and the filtrate made up to 250 ml. with water.

METHODS OF CHEMICAL ANALYSIS

The diets and feces were analyzed for their gross energy content using a Parr Oxygen Bomb Calorimeter.* Nitrogen analysis of the diets, urine and feces were done by the Kjeldahl - Gunning method using boric acid to retain the ammonia and mercury as a catalyst. Individual analyses of urine and feces were made for each pig and each rat on the metabolism experiments.

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* Parr Instrument Company, Moline, Illinois; Temperature changes registered by a Brown Electronik Recorder manufactured by Minneapolis - Honeywell Regulator Company, Philadelphia, Pennsylvania.

RESULTS AND DISCUSSION

ENERGY AND NITROGEN DIGESTIBILITY AND NITROGEN RETENTION EXPERIMENTS WITH SWINE

Digestibility of Energy

The data for apparent digestible energy (ADE) and the analysis of these data are given in Tables 2 and 3 for the 15 lb. pigs and in Tables 4 and 5 for the 100 lb. pigs.

ADE was not significantly influenced by the levels of fat or protein in the rations of either the 15 or 100 lb. pigs. However, the addition of 30% fat appeared to decrease ADE in the 15 lb. pigs. It also appeared that at a fat level of 30%, ADE on a percentage basis was lower for 15 lb. than it was for 100 lb. pigs. This latter observation would tend to support the observation that age of pigs influences ADE as has been shown by Lloyd *et al*. (1957).

Digestibility of Nitrogen

Nitrogen (N) digestibility coefficients for 15 lb. pigs are given in Table 2 and the analysis for these data in Table 3. Similar data for 100 lb. pigs are reported in Tables 4 and 5.

Neither energy nor protein levels of the ration had any significant effect on the percentage of apparent digestible nitrogen (ADN) in 15 lb. pigs. However ADN was improved by the addition of protein to the ration in the 100 lb. pigs. In previous studies, Likuski (1959) found that when rations containing 18% protein were fed to 15, 50 and 110 lb. pigs the coefficients of ADN were higher than when lower levels of 14 % protein were fed. Bowland *et al*. (1958) also found that the percentage ADN increased as nitrogen levels in the diet increased.

In the 100 lb. pigs the addition of fat tended to increase ADN but

TABLE 2

15 LB. PIG METABOLISM EXPERIMENTS - ENERGY AND NITROGEN DIGESTIBILITY AND NITROGEN RETENTION

	Fat - Protein*	Breed**	No. Pigs	Digestibility Energy %	Digestibility Nitrogen %	Retention Gross N %	Retention ADN %
Ration 1	0 - 14	1	1	88.8	89.8	30.9	34.4
		2	1	90.5	88.9	34.5	38.8
Mean				89.6	89.4	32.7	36.6
Ration 2	0 - 18	1	1	92.8	90.9	51.0	56.7
		2	1	92.6	90.8	60.6	66.7
Mean				92.7	90.4	55.8	61.7
Ration 3	0 - 22	1	1	88.6	86.8	31.2	35.9
		2	1	91.2	91.7	65.6	65.6
Mean				89.9	89.2	48.4	50.8
Ration 4	15 - 14	1	1	97.1	95.3	29.3	30.7
		2	1	92.8	92.3	47.6	51.6
Mean				95.0	93.8	38.4	41.2
Ration 5	15 - 18	1	1	87.9	85.6	62.0	72.5
		2	1	92.0	91.6	63.7	69.6
Mean				90.0	88.6	62.8	71.0
Ration 6	15 - 22	1	1	88.0	90.0	56.2	62.5
		2	1	93.0	92.7	53.6	57.8
Mean				90.5	91.4	54.9	60.2
Ration 7	30 - 14	1	1	89.3	87.6	52.2	59.6
		2	1	82.6	82.6	38.7	46.9
Mean				86.0	85.1	45.4	53.2
Ration 8	30 - 18	1	1	84.6	84.1	48.8	58.0
		2	1	87.1	89.2	55.9	62.7
Mean				85.8	86.6	52.4	60.4
Ration 9	30 - 22	1	1	89.9	91.2	64.8	71.1
		2	1	84.5	87.0	59.3	68.2
Mean				87.2	89.1	62.0	69.6

* The first figure represents supplemented fat levels and the second figure protein levels in the ration. This same method of representing rations is used in all future tables.

** 1 = Yorkshire
2 = Tamworth x Yorkshire

TABLE 3

15 LB. PIG METABOLISM EXPERIMENT - MEAN SQUARES OBTAINED
BY ANALYSIS OF VARIANCE OF TABLE 2

		Digestibility		Retention	
	DF	Energy	Nitrogen	Gross N	ADN
Total	17				
Energy	2	51.15	28.34	101.86	202.84
Protein	2	1.80	2.83	596.07	717.42
Breed	1	-	2.22	155.94	119.40
Energy x Protein	4	9.76	9.86	65.34	95.26
Energy x Breed	2	11.48	4.74	14.67	126.78
Protein x Breed	2	10.34	18.34	13.23	6.39
Error	4	8.09	6.15	118.16	110.79

TABLE 4

100 LB. PIG METABOLISM EXPERIMENT - ENERGY AND NITROGEN DIGESTIBILITY AND NITROGEN RETENTION

	Fat - Protein	Breed Period	Digestibility Energy %	Digestibility Nitrogen %	Retention Gross N %	Retention ADN %
Ration 1	0 - 14	1	84.5	79.1	48.0	56.8
		2	89.1	85.4	44.8	52.3
		3	90.0	84.1	45.8	54.4
		4	90.0	85.3	51.2	60.0
Mean			88.4	83.5	47.4	55.9
Ration 2	0 - 18	1	85.7	83.2	57.4	66.4
		2	84.8	82.5	59.1	66.9
		3	89.8	89.1	58.9	66.1
		4	90.0	88.4	59.0	66.7
Mean			87.6	85.8	58.6	66.5
Ration 3	0 - 22	1	94.5	94.3	43.6	51.3
		2	88.2	88.3	39.4	47.5
		3	91.7	91.6	49.8	54.3
		4				
Mean			91.5	91.4	44.3	51.0
Ration 4	15 - 14	1	89.9	85.9	48.8	56.1
		2	92.1	91.2	51.3	59.8
		3	85.6	81.3	47.7	58.7
		4	89.1	87.3	50.2	57.5
Mean			89.2	86.4	49.5	58.0
Ration 5	15 - 18	1	91.4	89.9	43.7	51.7
		2	90.7	88.9	39.5	46.5
		3	89.8	88.9	37.4	70.4
		4	91.5	87.9	48.3	54.9
Mean			90.8	88.9	42.2	55.9
Ration 6	15 - 22	1	92.2	92.4	51.2	59.7
		2	82.3	80.6	53.4	61.9
		3	92.8	93.0	48.2	55.7
		4	93.0	92.2	57.1	61.9
Mean			90.1	89.6	52.5	59.8
Ration 7	30 - 14	1	91.8	90.0	61.7	68.9
		2	90.7	90.5	58.8	66.3
		3	90.2	89.9	61.9	42.4
		4	91.4	89.8	63.1	70.2
Mean			91.0	90.0	61.4	62.0
Ration 8	30 - 18	1	80.9	80.7	45.6	53.4
		2	92.5	92.2	44.4	52.1
		3	92.2	89.3	40.5	66.6
Mean			89.2	88.4	45.4	57.1
Ration 9	30 - 22	1	92.4	94.1	40.0	47.9
		2	90.6	88.6	35.4	44.1
		3	91.4	91.5	16.9	18.4
		4	93.3	92.8	42.4	45.7
Mean			91.9	91.8	33.7	39.0

TABLE 5

100 LB. PIG METABOLISM EXPERIMENT - MEAN SQUARES OBTAINED
BY ANALYSIS OF VARIANCE OF TABLE 4

		Digestibility		Retention	
	DF	Energy	Nitrogen	Gross N	ADN
Total	34				
Energy	2	4.23	36.08	108.42	118.36
Protein	2	12.00	54.30*	253.46**	335.60**
Breed Period	3	8.93	6.17	86.59	40.35
Energy x Protein	4	8.77	11.75	386.34**	244.94**
Energy x Breed Period	6	7.71	4.13	2.80	75.34
Protein x Breed Period	6	16.69	27.42	2.04	94.26
Error	11	8.54	11.78	34.45	44.53

* Significant at $<$P 0.05
** Significant at $<$P 0.01

this increase was not significant. This increase was also evident in 15 lb. pigs but to a lesser extent. Asplund et al. (1960) working with 8 week old pigs also obtained an increase in ADN through the addition of 10 and 20% stabilized grease.

Nitrogen Retention

The data for N retention and the analysis of these data are given in Tables 2 and 3 for the 15 lb. pigs and in Tables 4 and 5 for the 100 lb. pigs.

Protein levels of 18 or 22% in the rations appeared to increase N retention above protein levels of 14% in 15 lb. pigs, however this increase was not statistically significant. With the 100 lb. pigs there was a decrease in N retention as protein levels increased. This decrease was not consistent at various levels of energy, hence there was an interaction between energy and protein levels.

The results, in general, agree with those of Mitchell and Hamilton (1935) and Bowland et al. (1958). As a pig's protein requirements decrease as it becomes older and heavier, the results are consistent with expectation.

DAILY GAIN, DAILY FEED, EFFICIENCY OF FEED UTILIZATION AND CARCASS CHARACTERISTICS OF SWINE

Daily Gain

Means for average daily gain are given in Tables 6 and 9 for the pigs used in the feeding experiments and metabolism experiments respectively. The analysis of the data is given in Tables 8 and 10.

In both feeding and metabolism experiments increases in either fat or protein levels increased rate of gain. These results are in agreement

TABLE 6

PIG FEEDING EXPERIMENTS - EXPT. 333 AND 333B
GAIN, FEED CONSUMPTION AND EFFICIENCY OF FEED UTILIZATION

Ration	Fat - Protein	No. of Pigs	Av. Daily Gain lb.	Av. Daily Feed lb.	Feed per lb. Gain lb.	ADE per lb. Gain* therms
1	0 - 14	7	1.13	3.51	3.12	4.91
2	0 - 18	8	1.42	3.94	2.78	4.49
3	0 - 22	8	1.46	4.17	2.86	4.75
4	15 - 14	8	1.30	3.12	2.41	4.76
5	15 - 18	8	1.57	3.38	2.16	4.30
6	15 - 22	7	1.44	3.27	2.30	4.35
7	30 - 14	7	1.48	2.92	1.98	4.29
8	30 - 18	8	1.47	2.69	1.82	3.93
9	30 - 22	8	1.67	2.88	1.72	4.05

* ADE per lb. gain = Feed/lb. gain x Gross Energy/lb. x % ADE.

TABLE 7

PIG FEEDING EXPERIMENTS - EXPT. 333 AND 333B
CARCASS DATA

Ration	Fat - Protein	No. of Pigs	Av. Backfat* in.	Area of loin sq. in.	Dressing Percentage %	Av. length of side in.
1	0 - 14	7	1.81	2.97	77.2	30.5
2	0 - 18	8	1.72	3.44	77.2	30.4
3	0 - 22	8	1.67	3.38	77.8	30.1
4	15 - 14	8	2.16	3.07	80.6	30.1
5	15 - 18	8	2.08	3.55	80.9	30.0
6	15 - 22	7	2.06	3.35	79.5	30.1
7	30 - 14	7	2.14	2.94	80.5	29.9
8	30 - 18	8	2.03	3.46	80.2	30.3
9	30 - 22	8	1.94	3.40	78.6	29.8

* Av. of shoulder and loin.

TABLE 8

MEAN SQUARES OBTAINED BY ANALYSIS OF VARIANCE OF DATA IN TABLES 6 AND 7

	DF	Av. Daily Gain	Av. Daily Feed	Feed per lb. Gain	ADE per lb. Gain	Dressing Percentage	Av. Backfat	Loin Area	Length of Side
Total	68								
Between Littermates	33	0.01	0.08	0.04	0.12	0.39	0.03	0.08	0.38
Energy	2	0.22**	6.56**	6.66**	2.24**	55.90**	0.88**	0.02	0.65
Protein	2	0.32	0.40*	0.39**	1.03**	6.00	0.13*	1.50**	0.35
Breed	1	0.03	0.05	0.01	0.09	0.20	0.06	0.14	1.40
Period***	1	0.00	0.58*	0.20**	1.46	7.20	0.86**	0.94**	1.50
Energy x Protein	4	0.08*	0.34*	0.05	0.03	3.38	0.00	0.03	0.25
Energy x Breed	2	0.08	0.14	0.50**	0.26	3.05	0.04	0.10	0.10
Protein x Breed	2	0.00	0.07	0.12	0.50*	1.95	0.01	0.15	0.35
Breed x Period	1	0.06	0.57*	0.05	0.05	7.40	0.01	0.65*	0.50
Error	20	0.02	0.04	0.01	0.13	4.16	0.01	0.11	0.49

* Significant at $P < 0.05$
** Significant at $P < 0.01$
*** Period as used in this thesis refers to replicate experiments conducted at different times.

TABLE 9

METABOLISM EXPERIMENT - RATE OF GAIN, FEED CONSUMPTION AND CARCASS DATA MEANS

Ration	Fat - Protein	No. of Pigs	Av. Daily Gain lb.	Av. Daily Feed lb.	Feed per lb. Gain lb.	ADE per lb. Gain therms	Av. Backfat* in.	Area of Loin sq. in.	Dressing Percentage %	Av. Length of Side in.
1	0 - 14	4	0.92	2.98	3.24	5.10	2.00	3.06	78.9	30.0
2	0 - 18	4	1.53	4.15	2.71	4.37	1.62	3.77	77.0	30.5
3	0 - 22	3	1.33	3.73	2.82	4.69	1.78	3.29	78.5	30.5
4	15 - 14	4	1.10	2.60	2.36	4.66	2.12	3.08	80.1	30.0
5	15 - 18	4	1.54	3.37	2.18	4.34	2.02	3.37	80.2	30.0
6	15 - 22	4	1.55	3.35	2.17	4.11	1.92	3.34	79.3	30.2
7	30 - 14	4	1.30	2.52	1.95	4.22	2.11	3.09	81.8	29.6
8	30 - 18	4	1.55	2.86	1.85	3.83	2.19	3.30	79.6	29.5
9	30 - 22	4	1.51	2.82	1.87	4.41	1.95	3.68	80.8	30.2

* Average of shoulder and loin.

TABLE 10

MEAN SQUARES OBTAINED BY ANALYSIS OF VARIANCE OF DATA IN TABLE 9

	DF	Av. Daily Gain	Av. Daily Feed	Feed per lb. Gain	ADE per lb. Gain	Av. Backfat	Area of Loin	Dressing Percentage	Length of Side
Total	34								
Energy	2	0.12**	2.20**	3.20**	0.74**	0.24**	0.04	20.75**	0.93
Protein	2	0.66**	1.86**	0.30**	0.57**	0.10**	0.58*	5.40	0.60
Breed Period	3	0.05**	0.05	0.63**	0.19**	0.11**	0.00	18.37**	0.27
Energy x Protein	4	0.03*	0.22	0.35**	0.23**	0.07*	0.21	2.42	0.24
Energy x Breed Period	6	0.02	0.04	0.01		0.09**	0.07	4.38	0.38
Protein x Breed Period	6	0.03*	0.14	0.03		0.02	0.18	3.05	0.73
Error	11	0.01	0.10	***		0.02	0.13	1.77	0.42

* Significant at $P < 0.05$
** Significant at $P < 0.01$
*** Obtained negative error S.S. therefore used first order interaction S.S. to get M.S.

with studies reported by Abernathy et al. (1958), who found that a highly significant increase in gain resulted when the energy levels of rations were increased, and by Bowland and Berg (1959) who reported that rate of gain tended to be greatest in the pigs fed high energy - high protein rations throughout the growing and finishing period. As indicated by a significant interaction between energy and protein levels in both the feeding and metabolism experiments, protein levels had less effect on rate of gain as fat levels in the rations increased.

In the metabolism trial different breeds were used in the two trials conducted and in the analysis the term "breed period" was adopted to refer to differences between the 2 trials because breed was confounded with period. Breed period affected daily gain which was higher in the second trial, indicating that there was a difference between either the pigs used in the two metabolism studies or that there were environmental differences between the two periods. In the metabolism experiment the breed x protein interaction was associated with the differences in magnitude of the increased average daily gain resulting from the addition of supplemental protein in the two trials. (Appendix Table 1)

Daily Feed Consumption

The data for average daily feed and the analysis of these data are given in Tables 6 and 8 for the feeding experiment and in Tables 9 and 10 for the metabolism trial. At any given level of fat in the ration, daily feed consumption tended to increase as daily rate of gain increased. In all cases increasing fat levels in the rations decreased feed consumption. Similar results have previously been reported by Perry et al. (1953), Baird and McCampbell (1960), Noland et al. (1960) and Pond et al. (1960).

In chicks, Hill and Dansky (1954) observed that feed intake was primarily controlled by the productive energy content of the diet. Similarly, Peterson _et al_. (1954) noted that as the productive energy content of the ration decreased feed intake increased.

Increases in protein level resulted in an increase in average daily feed intake. However, a greater increase occurred when the level was raised from 14 to 18% than from 18 to 22 percent. As a result a significant energy x protein interaction for feed intake with the pigs in the metabolism experiment was obtained.

In the feeding experiment the Landrace - Yorkshire pigs ate less feed in the first period and more feed in the second period than was eaten by the Yorkshire pigs resulting in a period x breed interaction. The significant period effect was associated with an overall increase in feed intake in the second period. While the feed intake of the Yorkshire pigs remained at the same level in both periods, the Landrace - Yorkshire pigs ate more feed in the second period. (Appendix Table 2)

Efficiency of Feed Utilization and ADE/lb. Gain

The data for efficiency of feed utilization and for ADE/lb. gain for the feeding experiment and the analysis of these data are given in Tables 6 and 8 and similar data for the metabolism trial in Tables 9 and 10.

Increasing fat levels in the ration improved efficiency of feed utilization which is in accordance with work reported by Abernathy _et al_. (1958) and Kennington _et al_. (1958). Increasing protein levels from 14 to 18 or 22% resulted in improved efficiency of feed utilization with greatest improvement occurring when the protein level was increased from 14 to 18 percent.

As indicated by the significant energy x protein interaction in the metabolism trial, protein levels had less effect on efficiency of feed utilization as fat levels in the rations increased. ADE per lb. gain also decreased as fat levels in the ration increased, indicating that the pigs were making more efficient utilization of the digestible energy from fat than of the energy from the basal ration. It must be recognized that ADE/lb. gain is a calculated figure based on the assumption that energy digestibility coefficients remained constant throughout the growing and finishing period, and that the coefficients obtained in the metabolism experiments can be applied to all pigs in the feeding experiments. Despite these limitations, the data suggest that the pig makes efficient metabolic use of digested fat.

In the feeding experiment a breed x energy interaction was associated with superior efficiency of feed utilization for the Landrace - Yorkshire pigs at 0 and 30% fat but a lower efficiency of feed utilization at the 15% supplemental fat levels as compared to the Yorkshire pigs. No explanation can be given for this effect. The Landrace - Yorkshire pigs were more efficient in utilization of feed in the first period and less efficient in the second period than the Yorkshire pigs resulting in a significant period effect. This was probably associated with the differences in feed intake between the breeds in the two periods. The Landrace - Yorkshire pigs required less ADE/lb. gain at 0 and 15% supplemental fat levels but more ADE/lb. gain at 30% levels of fat than did the Yorkshire pigs. (Appendix Tables 3, 5 and 6)

In the metabolism experiment the Yorkshire and the Tamworth - Yorkshire pigs in period 1 had similar efficiencies of feed utilization

but were less efficient than the Yorkshire and the Lacombe - Yorkshire pigs in the second period. The Yorkshire and the Lacombe - Yorkshire in the second period also had similar efficiencies of feed utilization. It would appear that period rather than breed had the major effect on the feed required per lb. gain. ADE/lb. gain showed similar results to those reported for efficiency of feed utilization. (Appendix Tables 4 and 7)

Carcass Characteristics of Market Swine

The data for carcass characteristics of market swine and the statistical analysis of these data are given in Tables 7 and 8 for the feeding experiment and in Tables 9 and 10 for the metabolism trial.

Dressing percentage based on hot carcass weight was raised when energy levels of the rations were increased by the addition of supplemental fat. Similar results were reported in energy and protein studies by Bowland and Berg (1959).

Increases in fat levels in the rations resulted in a greater depth of average backfat. Kennington *et al*. (1958) also reported an increase in backfat thickness from the addition of fat to swine rations. As protein levels increased, average backfat decreased but the change in thickness was not as great as that associated with fat levels in the ration.

Loin area in the pig carcasses was independent of the level of energy in the ration but increased when the protein level was increased. The observation that protein level in the ration influences loin area agrees with several reports including that of Bowland and Berg (1959).

Length of side was not affected by fat or protein level. This has previously been observed by Bowland and Berg (1959) and Likuski (1959).

In general, the carcasses of pigs receiving fat were inferior and less desirable than were carcasses of pigs not receiving fat. The major effect resulting from the addition of fat to the ration was the increased carcass backfat.

In the feeding experiment both breeds had greater backfat thickness in period 1 than in period 2, which resulted in a significant period effect. Both breeds had larger loin areas in period 2 as compared to period 1. In period 1, the Landrace - Yorkshire pigs had a larger area of loin than the Yorkshire pigs while in period 2 this effect was reversed resulting in a significant breed x period interaction. (Appendix Tables 8 and 10)

In the metabolism experiment the pigs in period 1 had a greater depth of backfat than those in period 2. An energy x breed - period interaction for average backfat was difficult to interpret as each breed seemed to behave differently at different levels of supplemental fat. The Lacombe - Yorkshire showed little change in average backfat thickness at different levels of fat while the Tamworth - Yorkshire pigs became progressively fatter as fat levels increased. The supplemental fat levels in the ration of the Yorkshire pigs had an intermediate effect on average backfat. (Appendix Table 9)

ENERGY AND NITROGEN DIGESTIBILITY AND NITROGEN RETENTION EXPERIMENT WITH RATS

Energy digestibility data and analysis of these data are given in Tables 11 and 12.

TABLE 11

RAT METABOLISM EXPERIMENT - ENERGY AND NITROGEN DIGESTIBILITY AND NITROGEN RETENTION

	Fat - Protein	Rep	Digestibility Energy %	Digestibility Nitrogen %	Retention Gross N %	Retention ADN %
Ration 1	0 - 14	1	85.5	76.2	47.7	62.6
		2	88.8	81.2	54.9	67.6
		3	89.4	80.0	58.4	73.0
		4	90.6	89.9	40.7	45.2
Mean			88.6	81.8	50.4	62.1
Ration 2	0 - 18	1	89.6	83.2	58.2	70.0
		2	85.8	81.4	52.1	65.2
		3	86.1	84.7	55.0	65.0
		4	88.5	87.3	54.6	62.5
Mean			87.5	84.1	55.2	65.7
Ration 3	0 - 22	1	85.4	81.1	54.7	67.5
		2	80.6	81.5	52.5	64.4
		3	84.5	84.5	39.5	46.7
		4	84.5	82.4	49.9	60.7
Mean			83.8	82.4	49.9	60.7
Ration 4	15 - 14	1	86.7	80.0	51.2	64.0
		2	89.7	85.8	55.9	65.1
		3	89.7	86.2	51.1	59.3
		4	92.4	90.9	52.0	57.2
Mean			89.6	85.7	52.6	61.4
Ration 5	15 - 18	1	88.2	85.1	61.5	72.3
		2	88.7	86.5	59.2	68.5
		3	90.3	86.8	58.1	66.9
		4	91.3	89.1	66.1	74.2
Mean			89.6	86.9	61.2	70.5
Ration 6	15 - 22	1	89.4	85.7	55.2	64.4
		2	89.7	87.9	61.4	69.8
		3	88.0	83.0	52.3	63.0
		4	88.4	87.3	60.9	69.7
Mean			88.9	86.0	57.4	66.7
Ration 7	30 - 14	1	91.5	87.7	62.3	71.1
		2	92.3	90.3	59.4	65.9
		3	89.2	85.1	64.2	75.4
		4	90.4	90.1	64.5	71.6
Mean			90.8	88.3	62.6	71.0
Ration 8	30 - 18	1	88.8	86.1	65.6	76.3
		2	86.6	82.4	56.6	68.8
		3	88.7	84.8	51.3	60.5
		4	89.9	86.7	60.6	69.9
Mean			88.5	85.0	58.5	68.9
Ration 9	30 - 22	1	88.8	88.0	62.9	71.5
		2	87.3	87.4	50.2	57.4
		3	87.7	84.8	64.3	75.8
		4	81.3	78.1	37.2	47.6
Mean			86.3	84.6	53.6	63.1

TABLE 12

RAT METABOLISM EXPERIMENT - MEAN SQUARES OBTAINED
BY ANALYSIS OF VARIANCE OF DATA IN TABLE 11

		Digestibility		Retention	
	DF	Energy	Nitrogen	Gross N	ADN
Total	35				
Energy	2	13.92	43.62*	140.28	76.20
Protein	2	39.89**	3.94	68.42	76.86
Energy x Protein	4	9.71	12.03	61.49	52.40
Replicate	3	0.46	16.91	19.33	59.00
Error	24	5.24	10.01	42.08	42.17

* Significant at $P < 0.05$
** Significant at $P < 0.01$

ADE decreased as protein levels increased in the diets of rats. In contrast, Bowland et al. (1958) reported that N levels had no effect on ADE when rats were fed diets varying from 0 to 30% corn oil. No reason can be advanced for these differing results except that stabilized tallow and corn oil might behave differently as fat sources. The work of Asplund et al. (1960) would support this hypothesis.

ADE was not influenced by fat levels in the diet. The earlier studies of Bowland et al. (1958) also found no definite influence of fat levels on ADE although the data suggested that there might be a decrease in ADE as the levels of fat increased.

Consumption and Digestion of Nitrogen

The data for N consumption and the analysis of these data are in Tables 13 and 14 while the data for N retention and the analysis of these data are in Tables 11 and 12.

As expected from the experimental design, rats fed diets high in protein consumed the greatest amount of N. Increasing fat levels in the diets resulted in decreased N consumption which was associated with the lowered feed intake on the higher energy diets.

Protein levels did not significantly affect ADN which differs from results reported by Bowland et al. (1958) who found that the percentage ADN increased as N levels in the diet increased. There was a trend for ADN to increase as protein levels increased at fat levels of 0 and 15% but this trend reversed when the fat level was increased to 30 percent. Likuski (1959) found that the percentage ADN was not significantly influenced by the level of protein in the diet, however, the percentage ADN tended to be higher for diets high in protein.

TABLE 13

RAT METABOLISM EXPERIMENT - BODY WEIGHTS, FOOD CONSUMPTION[1] AND EFFICIENCY OF FOOD UTILIZATION

			Metabolism Period			Per 100 gm. Body Weight			
	Fat - Protein	Rep	Gain in Wt.	Av. Body Wt.	Food/gm. Gain	Av. Weekly Gain	Food Cons.	ADE Cons.	Gross N Cons.
			gm.	gm.	gm.	gm.	gm.	Cal.	mg.
Ration 1	0 - 14	1	26	70	3.0	37	112	389	2349
		2	29	72	3.0	40	120	435	2529
		3	28	70	3.1	40	127	462	2667
		4	16	66	3.8	24	89	329	1874
Mean			25	70	3.2	35	112	404	2355
Ration 2	0 - 18	1	43	85	2.1	50	106	376	2947
		2	32	71	2.2	45	100	340	2325
		3	42	79	2.0	53	108	369	3012
		4	42	85	2.0	49	97	341	2708
Mean			40	80	2.1	49	103	356	2748
Ration 3	0 - 22	1	52	90	1.8	58	104	364	3614
		2	45	79	1.9	57	109	359	3780
		3	29	75	2.7	39	104	357	3589
		4	47	80	2.0	59	117	404	4052
Mean			43	81	2.1	53	108	371	3759
Ration 4	15 - 14	1	12	66	5.0	18	95	399	2052
		2	25	70	2.6	36	94	454	2024
		3	20	67	2.9	30	86	373	1857
		4	17	66	3.4	26	89	398	1924
Mean			18	67	3.5	28	91	406	1964
Ration 5	15 - 18	1	37	78	1.9	47	90	372	2581
		2	36	74	1.9	49	91	382	2635
		3	40	84	1.9	48	90	380	2578
		4	42	76	1.8	55	97	415	2785
Mean			39	78	1.9	50	92	387	2645

1 Air-dry Basis

TABLE 13 (CONTINUED)

RAT METABOLISM EXPERIMENT - BODY WEIGHTS, FOOD CONSUMPTION AND EFFICIENCY OF FOOD UTILIZATION

			Metabolism Period			Per 100 gm. Body Weight			
	Fat - Protein	Rep	Gain in Wt. gm.	Av. Body Wt. gm.	Food/gm. Gain gm.	Av. Weekly Gain gm.	Food Cons. gm.	ADE Cons. Cal.	Gross N Cons. mg.
Ration 6	15 - 22	1	42	79	1.6	53	88	389	3132
		2	39	77	1.8	51	89	393	3154
		3	41	80	1.6	51		368	3009
		4	37	77	1.8	48	87	380	3098
Mean			40	78	1.7	51	87	382	3098
Ration 7	30 - 14	1	24	70	2.7	34	94	462	2357
		2	15	64	3.1	23	71	351	1773
		3	23	76	2.2	30	84	402	2102
		4	24	68	2.2	35	77	375	1934
Mean			22	70	2.6	30	81	398	2042
Ration 8	30 - 18	1	44	87	1.8	51	88	416	2899
		2	32	73	1.9	44	84	388	2768
		3	18	69	2.2	26	58	276	1920
		4	23	69	2.1	33	68	326	2244
Mean			29	74	2.0	38	74	352	2458
Ration 9	30 - 22	1	46	86	1.5	53	79	383	3148
		2	35	75	1.6	47	74	350	2553
		3	38	74	1.8	51	93	446	3707
		4	32	78	1.2	41	47	210	1888
Mean			38	78	1.5	48	73	347	2824

TABLE 14

MEAN SQUARES OBTAINED BY ANALYSIS OF VARIANCE OF DATA IN TABLE 13

	DF	Av. Body Wt. Metab. Period	Av. Weekly Gain	Food Cons.	ADE Cons.	Gross N Cons.	Food/gm. Gain
Total	35						
Energy	2	26.00	143.68	2961.50**	2117	854,658**	0.65
Protein	2	370.50**	1248.86**	105.00	5315	3,688,122**	5.95**
Energy x Protein	4	13.50	53.28	43.25	376	163,234	0.30
Rep	3	66.33	29.58	160.67	2843	138,955	0.20
Error	24	22.08	48.33	109.04	2404	128,331	0.20

*   Significant at $P < 0.05$
** Significant at $P < 0.01$

N digestibility was improved by the addition of fat to the diet of rats. Similar results have previously been reported by Bowland *et al.* (1958).

Nitrogen Retention

The data for N retention and analysis of these data are given in Tables 11 and 12.

Neither energy nor protein levels significantly influenced N retention in weanling rats. Increased fat levels, however, appeared to increase gross N retained. Bowland *et al.* (1958), working with rats found that high fat diets increased gross N retention.

Average Body Weight, Rate of Gain, Food Consumption and Efficiency of Food Utilization

The data for average body weight, rate of gain, food consumption and efficiency of food utilization for the rats on metabolism studies are given in Table 13 with the statistical analysis of these data reported in Table 14.

To adjust for weight differences between rats during the metabolism period, average weekly gain as well as food, ADE, and gross N consumption during the metabolism period were compared on a 100 gm. body weight basis.

The level of protein in the diets affected average body weight, average weekly gain and air - dry food consumed per gm. gain. An increase in protein level, especially from 14 to 18%, resulted in increased average body weights and increased weekly gains. Efficiency of food utilization was improved with increasing levels of dietary protein, especially from 14 to 18 percent.

An increase in fat level decreased the amount of food consumed per 100 gm. body weight. Decreased food consumption as fat levels of the

ration increased was also observed in the swine trials.

RATE OF GAIN, FOOD INTAKE AND EFFICIENCY OF FOOD UTILIZATION EXPERIMENTS WITH RATS.

Rate of Gain

The data for rate of gain and the statistical analysis of these data are given in Tables 15 and 16.

In the feeding trial, increases in protein level of the diets increased rate of gain. Similar results have previously been reported by Bowland *et al*. (1958). These results are also in agreement with those obtained for swine.

The addition of fat to diets of rats had no appreciable effect on rate of gain, which is in contrast to results obtained for swine and those reported by Bowland *et al*. (1958) with rats. The data reported in the literature review, however, indicated that it is not uncommon to obtain no response in rate of gain to supplemental fat in the diet.

Statistical analysis showed a significant difference in rate of gain between replicates. This effect could be associated with environment or differences between rats. Connelly (1960) also obtained significant differences between replicates when he was working with the same strain of rats in the same colony. Since environmental differences were minimal, differences between rats seem to be the more likely explanation.

Food Intake

The data for food intake and statistical analysis of these data are given in Tables 15 and 16.

Additions of either energy or protein to the diets influenced food intake. Increases in protein appeared to increase food consumption, while increases in fat resulted in decreased food consumption. Similar

TABLE 15

RAT FEEDING EXPERIMENT - RATE OF GAIN, FOOD INTAKE AND EFFICIENCY OF FOOD UTILIZATION DATA

	Fat - Protein	Rep	Initial Wt. gm.	Final Wt. gm.	Total Wt. Gain gm.	Total Food Consumed gm.	Gm. Food/gm. Gain gm.	Av. Weekly Gain gm.	Av. Weekly Food Intake gm.
Ration 1	0 - 14	1	75.6	178.7	103.1	383.6	3.72	34.4	127.9
		2	47.9	127.7	79.8	355.5	4.45	26.6	118.5
		3	46.9	108.1	61.2	228.8	3.74	20.4	76.3
		4	37.2	105.6	68.4	238.5	3.49	22.8	79.5
Mean			51.9	130.0	78.1	301.6	3.85	26.0	100.6
Ration 2	0 - 18	1	61.1	184.4	123.3	336.1	2.73	41.1	112.0
		2	58.0	187.5	129.5	309.0	2.39	43.2	103.0
		3	43.6	162.4	118.9	288.5	2.43	39.6	96.2
		4	44.7	170.3	125.6	321.3	2.56	41.9	107.1
Mean			51.9	176.2	124.3	313.7	2.52	41.4	104.6
Ration 3	0 - 22	1	73.2	212.1	138.9	352.4	2.54	46.3	117.4
		2	50.9	173.4	122.5	296.4	2.42	40.8	98.8
		3	41.7	127.7	86.0	228.4	2.66	28.7	76.1
		4	40.4	169.8	129.4	279.8	2.16	43.1	93.3
Mean			51.6	170.8	119.2	289.2	2.44	39.7	96.4
Ration 4	15 - 14	1	63.6	137.0	73.4	217.4	2.96	24.5	72.5
		2	58.9	116.3	57.4	184.3	3.21	19.1	61.4
		3	45.2	98.2	53.0	172.8	3.26	17.7	57.6
		4	41.1	99.1	58.0	156.0	2.69	19.3	52.0
Mean			52.1	112.6	60.4	175.9	3.03	20.2	60.9
Ration 5	15 - 18	1	67.9	195.9	128.0	305.5	2.39	42.7	101.8
		2	54.0	158.5	104.5	238.1	2.28	34.8	79.4
		3	42.9	138.5	95.6	205.2	2.15	31.9	68.4
		4	44.2	150.6	107.0	234.8	2.19	35.7	78.3
Mean			52.2	160.9	108.8	245.9	2.25	36.3	82.0

TABLE 15 (CONTINUED)

RAT FEEDING EXPERIMENT - RATE OF GAIN, FOOD INTAKE AND EFFICIENCY OF FOOD UTILIZATION DATA

	Fat - Protein	Rep	Initial Wt. gm.	Final Wt. gm.	Total Wt. Gain gm.	Total Food Consumed gm.	Gm. Food/gm. Gain gm.	Av. Weekly Gain gm.	Av. Weekly Food Intake gm.
Ration 6	15 - 22	1	78.6	187.7	109.1	255.3	2.34	36.4	85.1
		2	45.0	177.6	132.6	245.2	1.85	44.2	81.7
		3	41.2	165.8	124.6	232.8	1.87	41.5	77.6
		4	45.0	180.0	135.0	259.2	1.92	45.0	86.4
Mean			52.4	177.8	125.3	248.1	2.00	41.8	82.7
Ration 7	30 - 14	1	71.6	162.1	90.5	245.4	2.71	30.2	81.8
		2	49.9	124.7	74.8	187.4	2.51	24.9	62.5
		3	45.8	94.8	49.0	151.6	3.09	16.3	50.5
		4	41.4	108.6	67.2	170.5	2.54	22.4	56.8
Mean			52.2	122.6	70.4	188.7	2.71	23.4	62.9
Ration 8	30 - 18	1	73.1	169.4	96.3	192.0	1.99	32.1	64.0
		2	48.8	166.6	117.8	197.4	1.68	39.3	65.8
		3	46.2	150.0	103.8	211.6	2.04	34.6	70.5
		4	36.8	140.9	104.1	193.6	1.86	34.7	64.5
Mean			51.2	156.7	105.5	198.6	1.89	35.2	66.2
Ration 9	30 - 22	1	75.7	204.1	128.4	248.8	1.94	42.8	82.9
		2	46.0	164.0	118.0	244.2	2.07	39.3	81.4
		3	51.7	135.3	83.6	176.3	2.11	27.9	58.8
		4	36.3	154.9	118.6	201.4	1.70	39.5	67.1
Mean			52.4	164.6	112.2	217.7	1.96	37.4	72.6

TABLE 16

MEAN SQUARES OBTAINED BY ANALYSIS OF VARIANCE
OF DATA IN TABLE 15

	DF	Av. Weekly Gain	Av. Weekly Food Intake	Food Cons. per Gram Gain
Total	35			
Energy	2	47.18	3626.32**	1.78*
Protein	2	962.08**	345.74*	4.18**
Energy x Protein	4	26.05	216.01	0.15
Replicate	3	103.86**	942.44 **	0.12
Error	24	15.60	88.52	0.48

* Significant at $P < 0.05$
** Significant at $P < 0.01$

results have been reported for the swine experiments. A significant difference in food consumption was obtained for replicates. A possible explanation could be similar to that given above for the replicate differences in rate of gain.

Efficiency of Food Utilization

The data for food utilization and analysis of these data are given in Tables 15 and 16.

Both fat and protein levels in the diet influenced efficiency of food utilization as increased levels of either resulted in increased efficiency. Similar results for both fat and protein were previously obtained by Bowland *et al*. (1958) when 0 to 30% corn oil was fed to rats.

PRACTICAL SIGNIFICANCE OF THE EXPERIMENTS

In addition to the experiments discussed in this thesis, a further preliminary experiment was conducted to study the effect on rate of gain, efficiency of feed utilization and carcass quality in market pigs when 15% stabilized tallow was added to the ration in the growing period only, finishing period only or throughout the entire growing - finishing period. Since this experiment has been published (Bowland and Kuryvial, 1961) it was omitted from this thesis. A general summary of the results of the experiment verified the data reported in the thesis in that "as a source of energy the fat is well utilized by pigs at a competitive cost with other sources of energy. However, results of experiments conducted during the past 2 years indicate that inferior carcasses are produced when 15 or 30% supplemental tallow is fed throughout the growing and finishing periods."

Fat levels of 15 and 30% are not practical for growing and finishing pigs because of their detrimental effect on carcass quality. From the

results obtained it appeared that high fat levels in rations for young pigs of 15 to 30 lb. had a beneficial influence on rate of gain, probably because of a favorable influence on energy consumption. At this stage the high energy rations presumably had a limited effect on final characteristics, so this aspect of fat supplementation of rations requires further study. Feeding fat only at certain stages of growth from 30 to 195 lb. may result in less harmful effects on the carcasses than feeding fat for the entire period, although the experiment of Bowland and Kuryvial (1961) was not too promising in this respect. Studies involving lower levels of supplemental fat (2 to 10%) appear to be warranted as these lower levels may prove to be practical. Feed manufacturers are using low fat levels of 2 to 3% as these levels do improve feed texture, reduce dustiness and decrease wear on mixing machinery.

There is conflicting evidence in the literature as to the extent that fat influences pig performance and carcass quality. Consequently, further research is required before a full evaluation can be made of fat as an energy source for pigs being fed to produce carcasses to satisfy Canadian grading standards and consumer preference.

SUMMARY AND CONCLUSIONS

The following results were obtained when rations containing 3 levels of energy (0, 15 and 30% supplemental fat) and 3 levels of protein (14, 18, and 22%) were fed to swine and rats. In the higher protein rations soybean oil meal and fish meal were increased at the expense of wheat. The fat was also added as a replacement for equivalent levels of wheat.

ENERGY AND NITROGEN DIGESTIBILITY AND NITROGEN RETENTION

Results obtained from the study suggest that fat levels in the diets of pigs and rats do not influence the ADE as the percentage ADE was not altered by the fat levels in the rations of weanling rats, 15 or 100 lb. pigs. Energy digestibility was not significantly influenced by the level of protein in rations of either 15 or 100 lb. pigs; however, with rats, increasing protein levels in the diets increased ADE.

ADN was not affected consistently by the addition of supplemental fat or by the protein level of the diets. ADN was increased when supplemental fat was added to the diets of rats but was not significantly influenced by fat levels in the rations of 15 or 100 lb. pigs, although with the 100 lb. pigs supplemental fat tended to increase ADN. Increased protein levels improved the percentage ADN of rations fed to 100 lb. pigs but not those fed to 15 lb. pigs or to rats.

Fat levels in the diets did not influence nitrogen retention in rats or in 15 or 100 lb. pigs. Nitrogen retention decreased as protein levels of the rations increased in 100 lb. pigs. In rats protein levels of the diet had no effect on nitrogen retention, while increased protein levels tended to improve nitrogen retention in 15 lb. pigs. These results indicate that both species and age or weight of an animal influence nitrogen retention when a given level of protein is fed.

RATE OF GAIN, FEED CONSUMPTION AND EFFICIENCY OF FEED UTILIZATION

Average daily gain in pigs was increased by the addition of either 15 or 30% supplemental fat or an increase in protein content of the ration from 14 to 18 or 22 percent. In the rat feeding experiment neither fat nor protein influenced rate of gain although during the metabolism trial rate of gain was increased by the addition of protein.

In all cases increasing fat levels in the ration decreased feed consumption while increases in protein levels resulted in an increase in average daily feed intake.

Increases in either fat or protein levels resulted in improved efficiency of food utilization in the swine and rat experiments. Similar results were obtained when efficiency of food utilization was converted to the basis of efficiency of ADE.

CARCASS CHARACTERISTICS OF MARKET SWINE

Dressing percentage, based on hot carcass weight, and the average backfat thickness were increased when energy levels of the rations were raised by the addition of supplemental fat. As protein levels increased average backfat decreased, but the change in thickness was not as great as that associated with changes in fat levels in the ration.

Loin area was independent of the level of energy in the ration but increased when the protein level was increased. Length of side was not affected by fat or protein levels of the rations.

In general, the carcasses of pigs receiving supplemental fat were inferior to carcasses of pigs not receiving fat. The major undesirable effect which would influence the commercial value of pigs was the increased backfat thickness of those receiving supplemental fat in their rations.

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APPENDIX

APPENDIX TABLE 1

BREED PERIOD AND PROTEIN EFFECTS ON AVERAGE DAILY GAIN (LB.) - METABOLISM EXPERIMENT

Breed	Period	Protein Levels %		
		14	18	22
Yorkshire	1	1.15	1.55	1.34
Tam. x York.	1	0.94	1.44	1.44
Yorkshire	2	1.17	1.55	1.54
Lac. x York.	2	1.16	1.62	1.62

APPENDIX TABLE 2

BREED PERIOD AND PERIOD EFFECTS ON AVERAGE DAILY FEED (LB.) - FEEDING EXPERIMENT

Period	Breed	
	Land. - York.	Yorkshire
1	3.17	3.30
2	3.54	3.30

APPENDIX TABLE 3

ENERGY X BREED EFFECTS ON FEED/LB. GAIN (LB.) - FEEDING EXPERIMENT

Breed	Energy Level (Fat %)		
	0	15	30
Land. - York.	2.83	2.32	1.81
Yorkshire	2.99	2.26	1.87

APPENDIX TABLE 4

BREED PERIOD EFFECTS ON FEED/LB.
GAIN (LB.) - METABOLISM EXPERIMENT

Breed	Period	Protein Level % 14	18	22	Breed Period Average
Yorkshire	1	2.54	2.33	2.36	2.44
Tam. x York.	1	2.53	2.36	2.34	2.44
Yorkshire	2	2.47	2.11	2.20	2.26
Lac. x York.	2	2.52	2.20	1.97	2.23

APPENDIX TABLE 5

PERIOD EFFECTS ON FEED/LB.
GAIN (LB.) - FEEDING EXPERIMENT

Period	Breed Land. - York.	Yorkshire	Period Average
1	2.26	2.33	2.30
2	2.42	2.38	2.40

APPENDIX TABLE 6

PROTEIN X BREED EFFECTS ON ADE/LB.
GAIN (THERMS) - FEEDING EXPERIMENT

Breed	Protein Level % 14	18	22
Land. x York.	4.50	4.15	4.52
Yorkshire	4.81	4.33	4.26

APPENDIX TABLE 7

BREED PERIOD EFFECT ON ADE/LB.
GAIN (THERMS) - METABOLISM EXPERIMENT

Breed	Period	Energy Level (Fat %) 0	15	30	Breed Period Average
Yorkshire	1	4.92	4.45	4.24	4.54
Tam. x York.	1	4.72	4.68	4.24	4.55
Yorkshire	2	4.50	4.06	4.19	4.25
Lac. x York.	2	4.68	4.31	4.14	4.34

APPENDIX TABLE 8

PERIOD EFFECT ON AVERAGE BACKFAT
THICKNESS (INCHES) - FEEDING EXPERIMENT

Period	Breed Land. - York	Yorkshire	Period Average
1	2.00	2.12	2.06
2	1.86	1.81	1.84

APPENDIX TABLE 9

BREED PERIOD AND ENERGY X BREED PERIOD EFFECTS ON AVERAGE
BACKFAT THICKNESS (INCHES) - METABOLISM EXPERIMENT

Breed	Period	Energy Level (Fat %) 0	15	30	Breed Period Average
Yorkshire	1	1.80	2.22	2.32	2.11
Tam. x York.	1	1.85	2.02	2.18	2.02
Yorkshire	2	1.72	2.00	1.90	1.87
Lac. x York.	2	1.88	1.87	1.93	1.89

APPENDIX TABLE 10

BREED PERIOD AND PERIOD EFFECTS ON AREA OF LOIN (SQ. IN.) - FEEDING EXPERIMENT

Period	Breed		Period Average
	Land. - York.	Yorkshire	
1	3.32	3.04	3.19
2	3.36	3.47	3.42